MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

ENT3056 – ADVANCED FABRICATION TECHNOLOGY

(NE)

15 MARCH 2019
3.00 p.m. – 5.00 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

4. Please refer to APPENDIX at page 7 and 8 for a list of physical constants, a list of formulas, and the error function table.

QUESTION 1

(a) Distinguish the respective role of the following semiconductor foundries:
(i) Merchant foundry,
(ii) Pure-play foundry,
(iii) Integrated device manufacturer. [6 marks]

(b) With the aid of a schematic diagram, describe the basic process flow from starting material to polished silicon (Si) wafers. [4+6 marks]

(c) A Si boule is pulled from the melt of electronic grade Si and Boron (B) dopant, which is contained in a crucible of a crystal puller. The Si boule is sliced into thin sheet of wafers. The wafer taken from the top of the Si boule has a doping concentration of 3×10^{15} cm^{-3}. Determine the doping concentration of the wafer taken from the position corresponding to 70 % of the initial charge solidified, given that the segregation coefficient (k) for B dopant of 0.8. [5 marks]

(d) Elaborate two main reasons for which the thermal evaporation technique is displaced by magnetron sputtering technique in most silicon technologies nowadays. [4 marks]

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QUESTION 2

(a) Distinguish the characteristic of the constant-source diffusion and limited-source diffusion processes. Describe the respective role of these processes in the microelectronic doping processing. [4 marks]

(b) With the aid of sketches, discuss the formation of silicon on insulator (SOI) wafers through the ion implantation process using oxygen as an implanted medium. [6 marks]

(c) Phosphorous (P) dopant atoms are implanted into a silicon substrate to form a *N*-well region. The projected range of the implanted dopant profile is 2000 Å. Take the standard deviation of the projected range as 500 Å. Given an implantation dose of 2×10^{10} cm^{-2}, determine the depth of the peak of the implanted profile, and the peak concentration of the P dopant atoms. [3 marks]

(d) A boron (B) pre-deposition is performed at 1000 °C for 30 minutes on a *N*-type silicon wafer which has a uniform background concentration of 3×10^{18} cm^{-3}. The B concentration at the surface is 2.5×10^{19} cm^{-3}. The diffusion coefficient for B at 1000 °C is given as 2×10^{-14} cm^2s^{-1}. Determine the junction depth following the B pre-deposition process. Refer to page 8 for the error function table. [6 marks]

(e) Ion implantation is used extensively in the semiconductor technology for a wide range of application including those given in Table 1 below. Provide one device example for these applications given in Table 1.

Table 1

Application	Device
Fabrication of junction	
Base formation	
Arsenic-implanted poly-si Emitter	
Emitter formation implantation	
Formation of source and drain region SOI using O_2 (SIMOX) and N_2 implantation	

[6 marks]

Continued .....

QUESTION 3

(a) One of the most important steps in the photolithography process is mask alignment and exposure.

(i) Describe the details of these important steps. [4 marks]

(ii) Compliment the following performance factors of the positive and negative photoresists (PR), respectively, given in Table 3(a). [4 marks]

Table 3(a)

Performance factors	Negative PR	Positive PR
Step coverage		
Exposure speed		

(iii) Given a proximity photolithography exposure system with an exposure wavelength of 300 nm and a resist constant of 0.85. Determine the gap required between the mask and the silicon wafer for this proximity exposure system to achieve a 600 nm resolution. [2 marks]

(b) Figure 3(b) demonstrates the metal patterns fabricated using Etch-Back and Lift-Off processes, respectively. Draw the fabrication process flow for the metal patterns using Etch-Back and Lift-Off techniques, respectively. [8 marks]

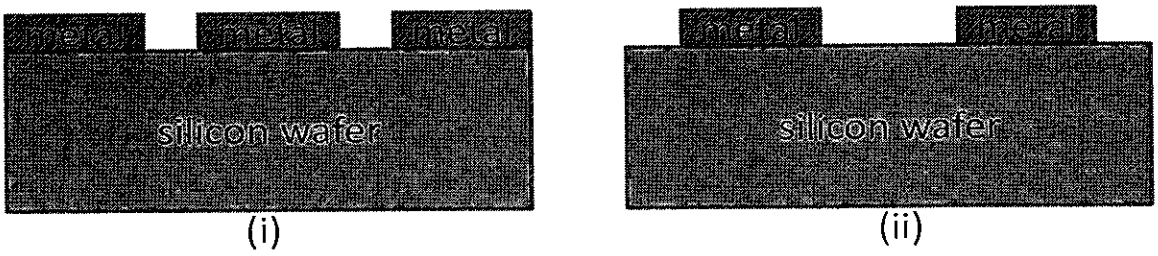

Figure 3(b): Metal patterns fabricated using (i) Etch-Back and (ii) Lift-Off techniques.

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QUESTION 3

(c) Figure 3(c) shows the schematic cross-section of a n-type zinc oxide/p-type gallium nitride (n-ZnO/p-GaN) light-emitting diode (LED) on an aluminum oxide (Al_2O_3) substrate. The metal contacts for the n-ZnO and p-GaN layers are made of titanium/gold (Ti/Au) bi-layers. Design the fabrication process for the LED by sketching the cross-sectional structure upon each of the process step. Label the structures, state the processes, and indicate both the mask patterns and type of resist clearly. [7 marks]

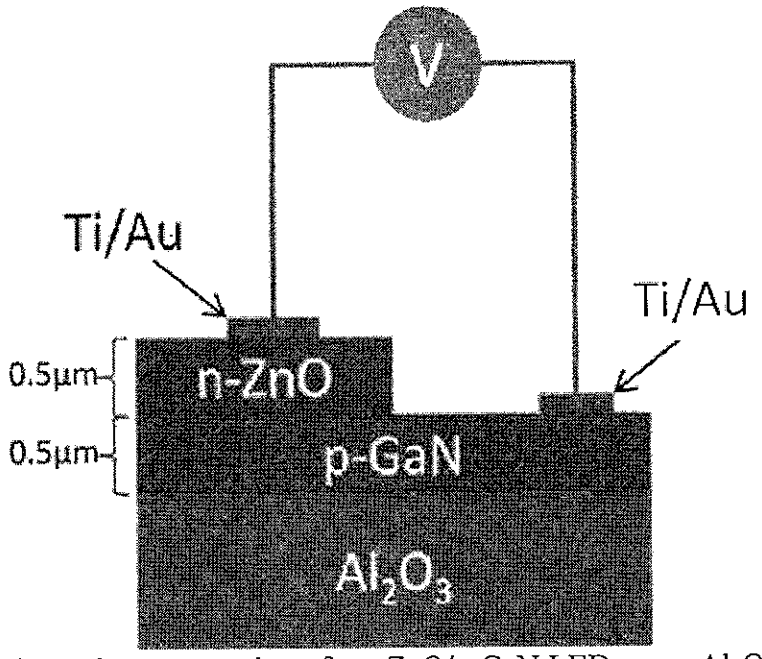

Figure 3(c): Schematic cross-section of a n-ZnO/p-GaN LED on an Al_2O_3 substrate.

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QUESTION 4

(a) Elaborate the term "local interconnects" in the context of contact metallization in microelectronic devices. [3 marks]

(b) In an effort to reduce the resistance-capacitance (R-C) time constant delay in order to improve the switching speed, a microelectronic firm has decided to replace aluminum (Al) (ρ=2.7 $\mu\Omega$-cm) with copper (Cu) (ρ=1.7 $\mu\Omega$-cm) wire, and silicon oxide (SiO_2) (k=3.9) with a low-k dielectric material (k=2.5), respectively. Estimate the percentage of reduction in the R-C time constant delay. [3 marks]

(c) Practically, there is always contact resistance presents at a semiconductor and metal contact layer interface of microelectronic devices such as field effect transistors.

(i) Describe the impact of the contact resistance on the field effect transistor performances. [4 marks]

(ii) Suggest a way to minimize the contact resistance. [4 marks]

(d) Given that the film resistivity is 21 μohm-cm, determine the thickness for a titanium silicide film with a measured sheet resistance of 0.9 ohm/□. [2 marks]

(e) Thin film silicon solar cells are second generation solar cells made with thin film silicon layers, and front and back contacts.

(i) Describe the requirements of the front and back contacts of a thin-film silicon solar cell. [2 marks]

(ii) Based on the requirements, propose suitable materials to be used as front and back contacts for the solar cells, respectively. [2 marks]

(f) Assuming there are two choices of metallization material to be adopted, namely copper (Cu) and silver (Ag). Given that the metallization diffusion into the semiconductor layer of the device is not a concern, but the R-C delay is a critical issue to device performance. Which metallization material would you adopt in the fabrication of the semiconductor device? Justify your selection. [2+3 marks]

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APPENDIX (Physical Constants):

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, k = 1.380622×10^{-23} J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, e = 1.60219×10^{-19} C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$X_j = R_P \pm \Delta R_P \sqrt{2\ln(N_P/N_B)}$	$N(x) = \frac{Q_o}{\sqrt{2\pi}\Delta R_p} e^{\left[-\frac{1}{2}\left(\frac{x-R_p}{\Delta R_p}\right)^2\right]}$
$x_j = 2\sqrt{Dt\ \ln(N_0/N_B)}$	$N(x,y) = \frac{N(x)}{\sqrt{2\pi}\Delta R_\perp} e^{\left[\frac{y^2}{2\Delta R_\perp{}^2}\right]}$
$x_j = 2\sqrt{Dt}\ erfc^{-1}(N_B/N_o)$	$C_s = \frac{Q}{\sqrt{\pi Dt}}$
$RC = \frac{R_s L^2 \in_{gd}}{d_{gd}} = \frac{\rho}{d_{poly-si}} \frac{L^2 \in_{gd}}{d_{gd}}$	$Q = 2C_s\sqrt{\frac{Dt}{\pi}}$
$C(x,t) = C_s erfc\left[\frac{x}{2\sqrt{Dt}}\right]$	$Q = \sqrt{2\pi} N_p \Delta R_p$
$C(x) = \frac{Q}{\sqrt{\pi Dt}} e^{-\left(\frac{x}{2\sqrt{Dt}}\right)^2}$	$C = k\,C_0\,(1-x)^{k-1}$
$W_{min} = k\{\lambda / NA\}$	$W_{min} = \sqrt{k\lambda g}$
$R_c = \rho_c / A, \qquad \rho = Rs \cdot t$	$k_0 = \frac{C_s}{C_l}$

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Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp\left(-t^2\right)$

erfc (t) = 1 - erf (t)

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